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72. On the Landslide Mechanism of the Tertiary Type Landslide in the Thaw Time

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1. Introduction

The landslides are the phenomena complicated by the mutual actions of nature, and therefore, it is difficult to detect the pre-eminent causes of the landslides.

The landslide phenomena can be divided geologically into three types as follows;

1) The landslide occurring in the tertiary formation zone (tertiary type landslide)
2) The landslide occurring in the crushing zone
3) The landslide occurring in the hotspring zone

Among them, the tertiary type landslide is the most impressive type in regard to scale and number. Compared with the other types, this bears a certain general character in the phenomena. Therefore, it is rather easy to discover the law of the predominant factor of the occurrence.

In this paper, an attempt has been made to explain the dynamical phase of soil block displacement of the representative tertiary type landslide by the observation of internal strain and soil pressure.

2. Outline of the observation area and its geological conditions

The landslide area at Tsukiike, Matsunoyama, Higashikubiki-gun, Niigata Pref., was selected for our observation. This landslide is considered as the tertiary type. The reasons why this area was selected are as follows. 1) As regards size, this slide is small (about 6 ha.), but its motion is very active, the displacement being about 6 meters a year. Hence the mechanism of this landslide can be studied in a short period of observation. 2) An earlier observation had been carried out by the members of the section of Sabo (erosion control) of Niigata Prefectural office from 1954 to 1960[1]. As a result, informations of the slide surface and the mechanism of displacement in summer term were obtained. Owing to them, our observation was carried out smoothly and the result of the present observation can be discussed in comparison with the previous one.

Historically, this area began to slide about 50 years ago. The displacement has increased since the beginnging of 1940. The soil disturbance was so heavy that even the finest rice field of this area at one time was damaged by innumerable cracks or faults. Geologically, it is on the west side of Matsunoyama Dome (tuff). This area is the lower Teradomari layer of Teradomari-Shinya formation in Late Miocene and consists of black shale, partly containing sandstone layers. The clay-mineral composition of chrolite in the sliding layer is not different from that of bed rock, but the former contains more clayey materials than the latter.

3. Observation

As shown in Fig. 1, two borings at every station, Nos. 1~8, were made, and chlorinated vinyl tubes were put into them. One of these two bore holes was for the measurement of internal strain, the other for that of soil pressure. Strain gauges were pasted on the outer sides of the vinyl tubes at intervals of 1 meter and then they were coated for water-proofing. The internal strain gauges were located and measured in the ordinary way[2]. As the soil pressure meter, to measure by the pipe strain, directly, each center of the four gauges was pasted at a quarter point of the circumference of the tube so that the longer side of it was at right angles to the direction of axis of the chlorinated vinyl tube. By this method, the adjoining gauges were connected and the measurement was carried out by the two gauges method.

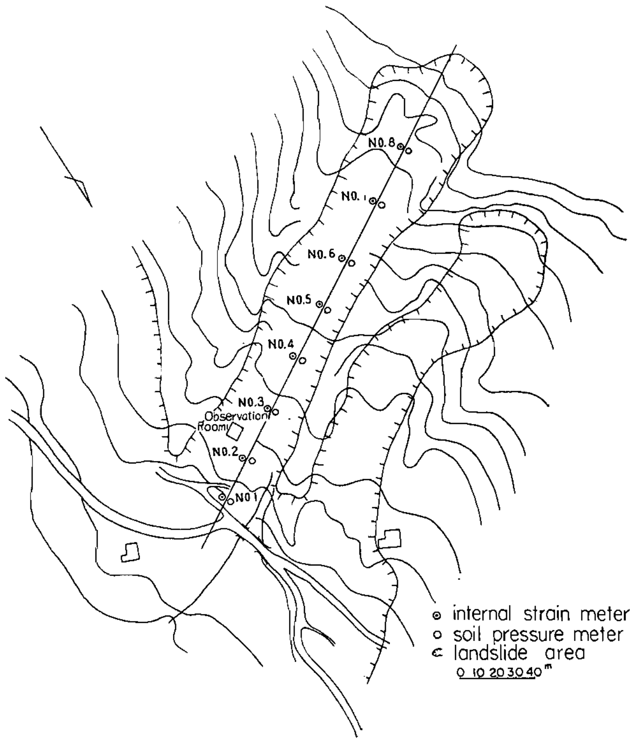

Fig. 1. Location of observation.

The depth of measuring point at each station is shown in Fig. 2. The deepest measuring point of the stations for internal strain meter was located in a depth of more than 0.5 meter under the upper boundary of bed

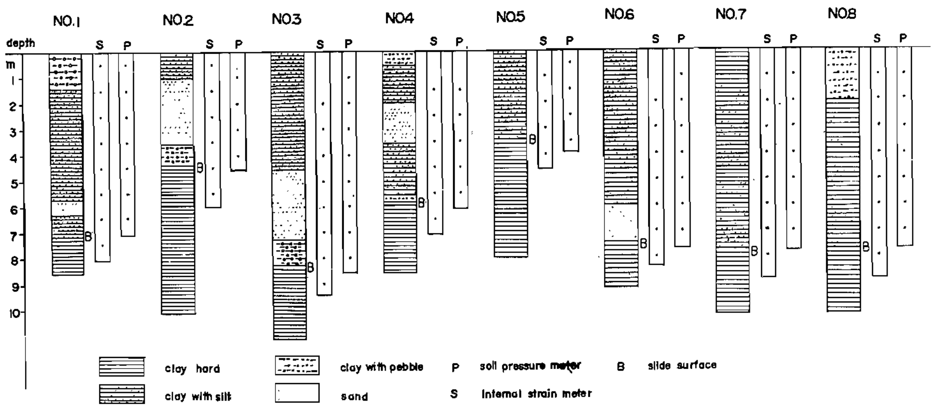

Fig. 2. Internal strain meters and soil pressure meters of each station, and its geological condition.

rock. And as regard to soil pressure meters, they were located so that the measurement could be carried out at intervals of 1 meter from the earth surface to the upper boundary of bed rock.

For the observation in the snowfall season, measurement cables were shielded and connected to the recorder in the observation room. The measurements were carried out every 3rd day from Dec. 10, 1962 to Apr. 30, 1963.

In order to avoid any influence by a bending of the chlorinated vinyl tube, notchs were made at the points 50 centi-meters below and above the gauge of the soil pressure. The values obtained by the measurement of soil pressures are proportional to the total weight within the limits of 50 kgw.

4. Analysis

I) Internal strain meter

The strain measurement of chlorinated vinyl tubes located in each measuring point was carried out every 3rd day on an average.

The strain variation of the chlorinated vinyl tube No. 1 at each depth is demonstrated in Fig. 3(a). It shows that the rate of strain increased on and after Feb. 24. The same fact is recognized, regarding Station Nos. 2, 3, 4 (Fig. 3(b), (c) and (d)). Station Nos. 1-1, 2 show a tendency to deform to the negative direction and Station Nos. 1-6, 8 to the positive one.

By this fact, if the whole active period is divided at Feb. 24 into two parts, the former active period and the latter one, the displacing mechanism is considered to be different between them.

II) Soil pressure meter

Some of the distribution of load at each measuring point are shown in Figs. 4(a), (b) and (c), where the positive value represents the compressive force to the landsliding direction, and the negative value is that to the direction perpendiculer to the landsliding one. In these figures, the negative value is neglected. Among Station Nos. 1~8, No. 6 shows distinctly the

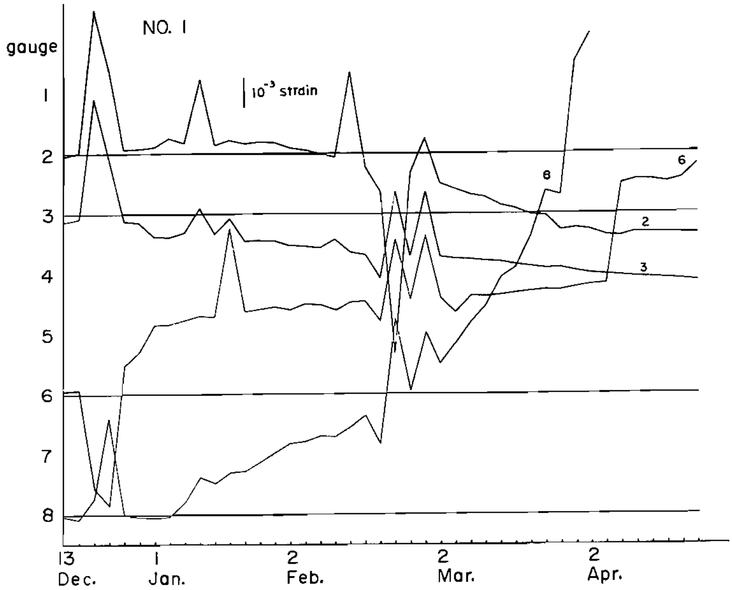
NO. 1
gauge
1
2
3
4
5
6
7
8
10⁻³ strain
13
Dec.
1
Jan.
2
Feb.
2
Mar.
2
Apr.

Fig. 3(a).

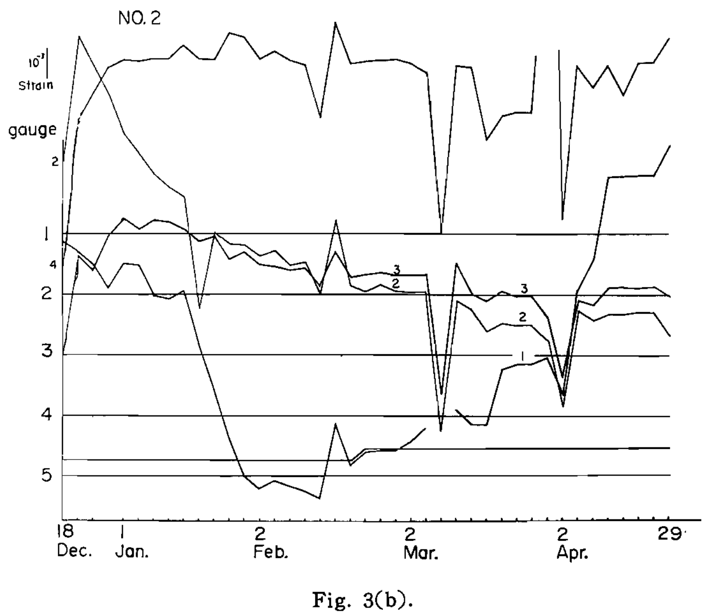
NO. 2
10⁻³ strain
gauge
2
1
4
2
3
4
5
18
Dec.
1
Jan.
2
Feb.
2
Mar.
2
Apr.
29

Fig. 3(b).

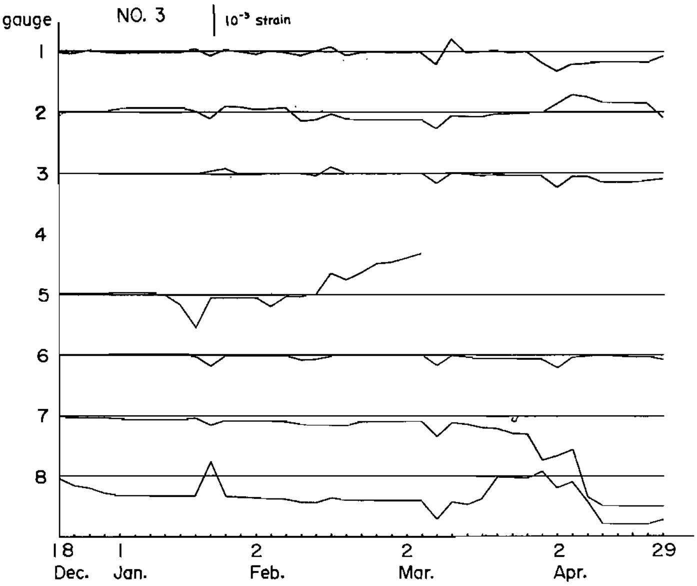

Fig. 3(c).

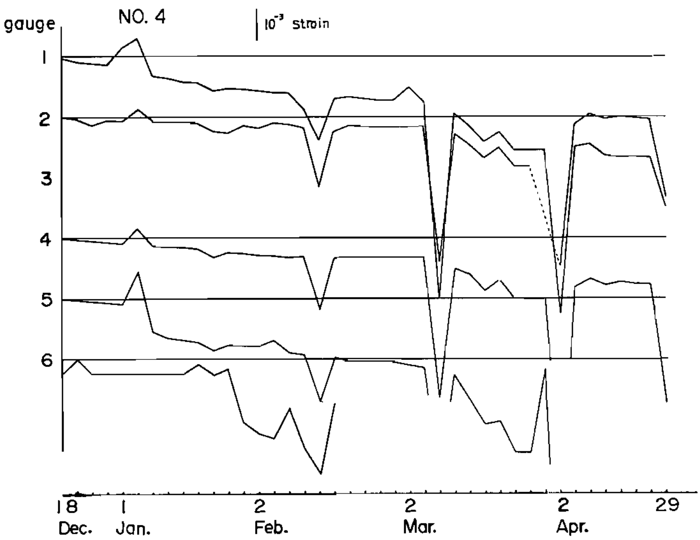

Fig. 3(d).

Fig. 3. The strain variation of the chlorinated vinyl tube at each meter of Nos. 1, 2, 3, 4 respectively.

difference of strain between the former period and the latter as mentioned above.

It is supposed that the displacing zone of landslide is divided into three, i) the surface layer, ii) the middle layer, iii) the lower layer. Figs. 5~7, show the variations at each measuring point in each layer. The surface layer is from 0.5 meter to 1 meter in depth. In the middle layer, soil pressures were observed at depths of 3.5, 2.5, 4.5, 2.5, 2.5, 3.5, 3.5, 3.5 meter, respectively from Station No. 1 to Station No. 8, and in the lower layer they were observed at the depths of 5.5, 3.5, 7.5, 5.5, 3.5, 6.5, 6.5, 6.5 meter. In the lowest layer, the soil pressures of Station No. 5 and Station No. 6 were high. In the middle layer, that of Station No. 3 was high. In the surface layer, the highest pressure was observed from Dec. 13 to Jan. 30 in Station No. 8, from Jan. 17 to Feb. 6 in Station No. 5, from Feb. 6 to 20 in Station No. 2 and from Feb. 27 to Apr. 30 in Station No. 1 respectively.

The propagation of soil pressure is not clear either in the lower layer or

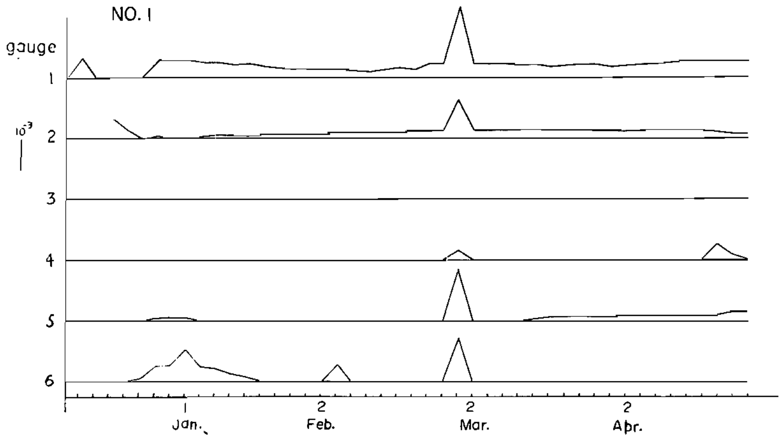

Fig. 4(a).

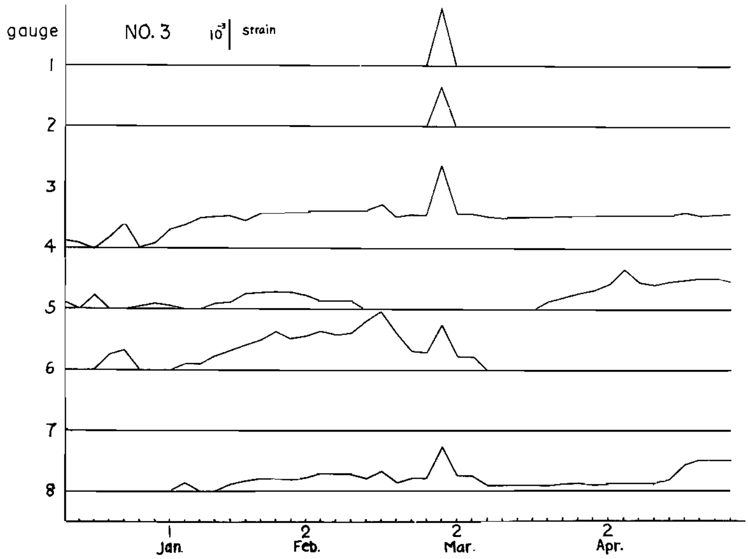

Fig. 4(b).

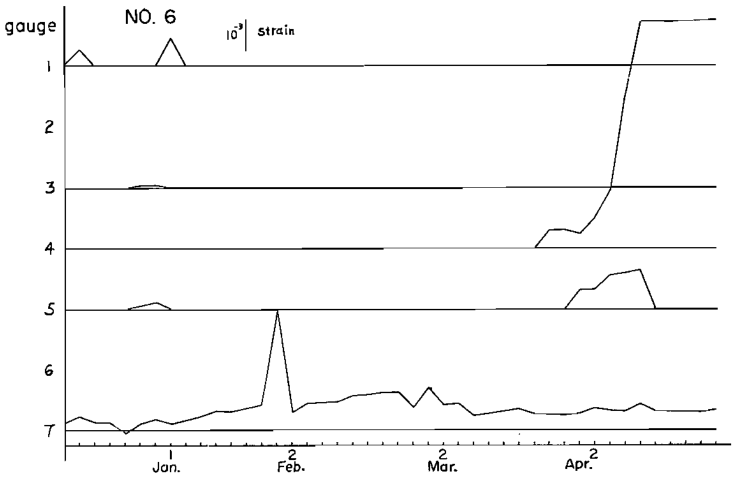

FIG. 4(c).

Fig. 4. The force of soil compression measured by strain gauges at Nos. 1, 2, 3, 6 respectively.

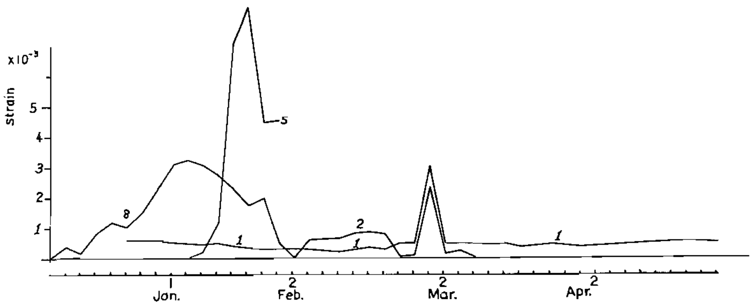

Fig. 5. The variation of force of soil compression at surface zone of each station.

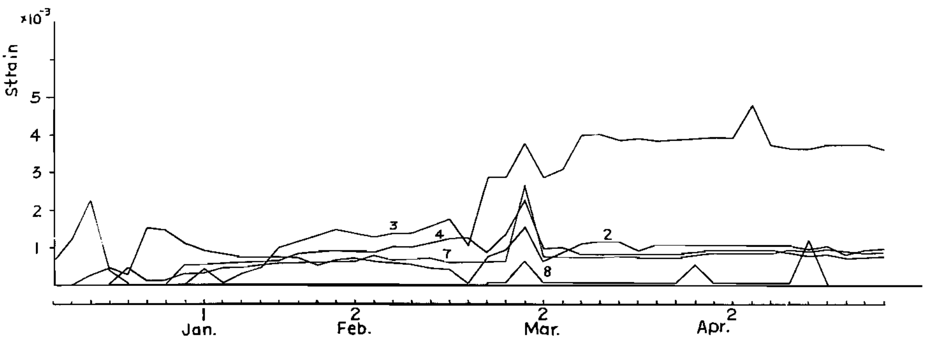

Fig. 6. The variation of force of soil compression at middle zone of each station.

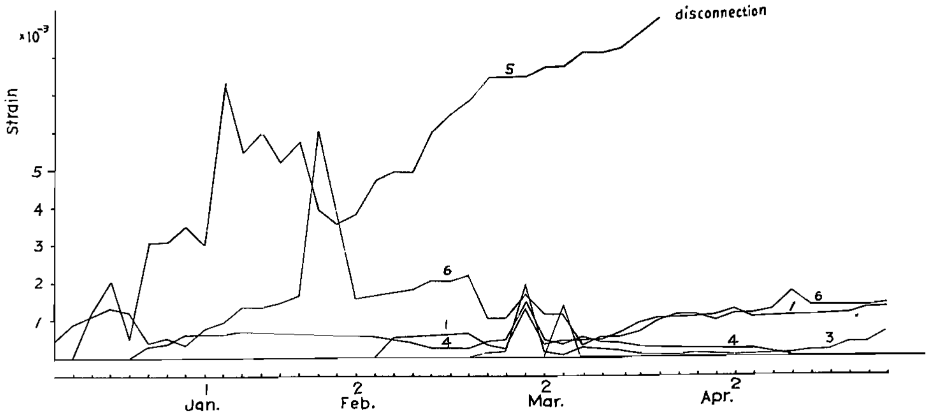

Fig. 7. The variation of force of soil compression at lower zone of each station.

in the middle layer. It is recognized that the soil pressure moves gradually from Station No. 8 to Station No. 1 in the surface layer. The increase of soil pressure can not be found except at Station Nos. 8, 5, 2 and 1.

The propagation of the soil pressure is explained as follows. As Station Nos. 7, 6 and Station Nos. 4, 3 move with block movement and stop at the boundary of each block boundary zone, so the soil pressures are observed only at Station Nos. 8, 5, 2. From this point of view, the propagation of this landslide is divided into four blocks; viz, (1) from the top of the landslide area to Station No. 8, (2) from Station No. 7 to Station No. 5, (3) from Station No. 4 to Station No. 2, (4) from Station No. 1 to the end place of the landslide. On the other hand, considering the slide surface of each station which was defined by each check boring, the landslide is divided into four soil blocks also, which are equal to the blocks assumed by measuring soil pressure.

III) Variation of the displacement zone

The values of internal strain obtained by measuring the deformation of chlorinated vinyl tube do not, strictly speaking, represent the displacement of the soil block. Because of its elasticity, the results measured by it contain not only the true soil displacement, but the elastic soil deformation also. In this paper, as the displacement of the soil in the landslide is larger than the deformation of it, and the deformation of the vinyl tube has linear relation to the displacement of the soil block, so the values of vinyl tube deformation are equal to the soil block displacement.

These results are shown in Fig. 8, where a dotted line represents the slide surface assumed by coreboring. It shows that the values of internal strain increase gradually from the upper zone (5 meter in depth) to the lower (7.5 meter in depth) of slide layer, during Dec. 13~Dec. 20, in other words, the width of the slide layer increases gradually to the direction of the bed rock.

Tsumoto pointed out[3] that the soil pressure tends to move from the upper part of the lower of the concrete pile inserted vertically into the soil

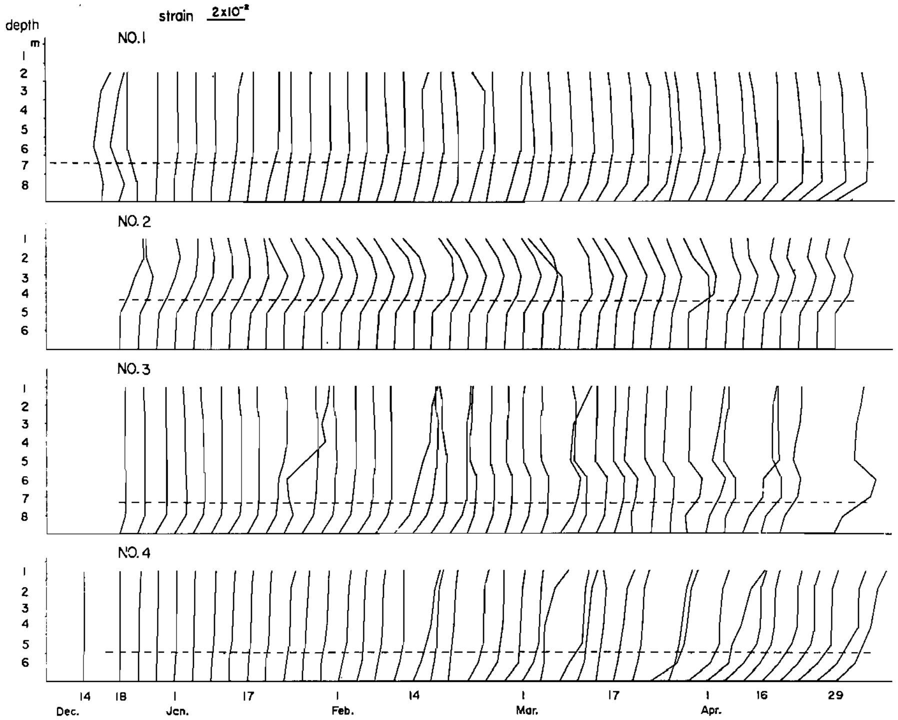

Fig. 8. The deformation of the chlorinated vinyl tube in Station Nos. 1~4 respectively.

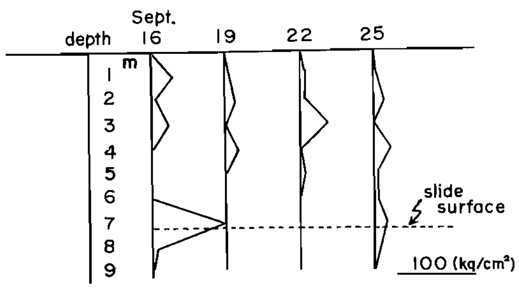

Fig. 9. The variation of the soil pressure near No. 1 (after Tsumoto).

at the same point as No. 1, during th summer term in 1960. (see Fig. 9)

Comparing with the facts above mentioned, it is clear that the displacement layer varies from the upper layer to the lower layer of the landslide zone at short times. After finishing this movement, the layer of the displacement removes again to the upper layer of the slide zone and the soil at the upper layer of it begins displacement too. But in this time, the movement of displacement zone is slower than the above-mentioned variation of slide zone in a short period.

When the layer of displacement reaches the boundary of the bed rock, the position of which is postulated on the base of the check boring, the area from the surface to the slide surface becomes the displacement zone and moves with the same speed from the surface to the boundary of the bed rock. This displacement continues to Apr. 30.

As Station No. 3, the layer of displacement is recognized in the lower section of slide zone. This main displacement of soil gradually varied from the lower part to the middle of the slide zone. In this case, this phenomenon does not imply the tunnel movement of the soil as mentioned by Tsumoto[4], but it means that the velocity of the displacement of the tunnel zone is faster than that of the upper section and the lower section of this slide zone. And at station No. 4, the upper section of slide zone moves remarkably. The results of these facts are given in Fig. 10.

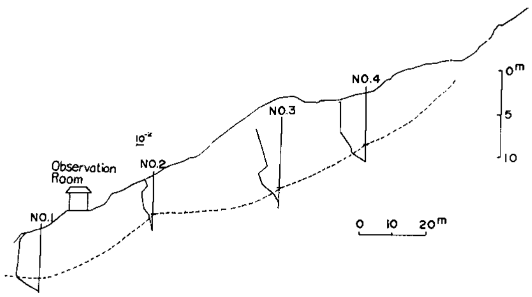

Fig. 10. The displacement zone profile of the slide layer.

4. Conclusion

The result of measuring by the internal strain meter and the soil pressure meter shows that the soil block moves gradually from the upper part to the lower of landslide area. And the depth where the displacement occurs is different at each station; viz, at some stations the deepest zone moves and at some the "tunnel movement of soil" occurs. When the displacement of landslide is maximum in each station, the displacement excels, as a rule, at the surface zone in which the depth from the soil surface to bed rock is shallow, but in the place where that depth is deep, the "tunnel movement of soil" is conspicuous. And at the terminal part of the active landslide area, the same displacement velocity is observed from the upper zone to the lower of the slide layer, as in Station No. 1. By observing the slide zone in the slide layer at one station during rather long period, an interesting phenomenon is observed that the slide zone does not exist always in the same place, but in other places too.

The writer wishes to express his hearty thanks to Dr. K. Sassa (President of Osaka Technological University), Prof. S. Yamaguchi (Disaster Prevention Research Institute of Kyoto Univ.) and Dr. M. Tsumoto (Erosion control section, Niigata Pref.) for their valuable guidances and instructions all the time throughout this study.

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Type Landslide, Report of the Landslide Survey, Niigata Pref. Erosion Control Section (1960).
2) Ibid.
3) Ibid.
4) Tumoto M. ; Geophysical Papers Dedicated to Prof. K. Sassa (1963), p. 634.